AN OSTEOLOGICAL STUDY ON THE SPERM WHALE *PHYSETER MACROCEPHALUS* LINNAEUS FROM INDIAN OCEAN

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ABSTRACT

The skeleton of a miafe sperm will? lie, *Physeter macrocephalus* Linnaeus (8.1 m) which was stranded on the southern side of Rmisadiai Island" (Gulf of Mannar) on 30th April 1980, is described in detail. The salient features are a trough-shaped asymmertrical skull, long 'V shaped mandible, a vertebral column consisting of seven cervical vertebrae (six of them fused, the first free), eleven thoracic vertebrae with only ten ribs, eight lumbar vertebrae and 23 caudal vertebrae with ten chevron bones attached between 3rd and 4th caudal vertebrae and fairly large forelimbs. Comparison of the skull of this specimen (8.1 m) with that of another male of an estimated length of 17. 4 m did not reveal any essential differences due to age. The osteofagical features in which the present material differs from others on record from elsewhere are mentioned.

INTRODUCTION

A male sperm whale, *Physeter macrocephalus* Linnaeus was stranded on 30th April 1980 on the southern side of Krusadiai Island (Gulf of Mannar). A detailed description of its morphological features has been given by James and Soundararajan (MS). The animal was buried by ithe authorities of the Department of Fisheries of Tamil Nadu on 3-5-1980 on /the shore, after removing the blubber for extracting oil. Parts of the skeleton examined by unearthing on 24-9-80 indicated that it was not yet clean. Later examination on 24-3-1981 had shown that all the skeletal parts were completely devoid of flash and otlier blood stains and were clean except for oozing of oil from the last few caudal vertebrae. Therefore, the skeleton was exhumed for detailed examination the same day. Except for sternal bones, pelvic bones, and some parts of both the forelimbs, all parts of the skeleton could be recovered intact.

The sperm whale is the largest of the toothed whales (Odontoceti) and one of the most peculiar and intriguing representatives of the entire order Cataacea (Berzin 1972). According to Berzin (1972), a detailed study of the skeleton of sperm whale has been made only by very few workers (Flower 1867, Baschma 1938, Beddard 1958, Slipjer 1958 and Omura at al 1962) and the knowledge on this subject is still inadequate. It is of interest to note that

nothing is known till date, about the osteology of the sperm whale from the Indian region obviously because of the very rare instance of stranding of the sperm whale along the Indian Coast. The present study its aimed at filling the gap in our knowledge of the osteology of the sperm whale from this part of the globe which would also contribute to the study of systematics of the species and an understanding of the functional morphology.

MATERIAL AND METHODS

1. A skeleton of a male sperm whale, *Physeter macrocephalus* Linnaeus, stranded at Krusadai Island (Gulf of Mannar) on 30th April, 1980'. The whale measured 8.1 metres from tip of snout to tail notch. The animal was buried on 3-5-1980 after removing the blubber for extracting oil and the skeleton was exhumed on 24-3-1981. The skeleton is deposited in the Museum of the Mandapam Regional Centre Marin© Fisheries Institute, Mamdapani Camp.

2. The skull (4.45 m - condylo-basal length) of a sperm whale stranded at Manuali Island (Gulf of Mannar) in July 1979. The estimated total length of the whale was 17.4 m and from the size it was surmised to be a male (James and Soundamarajan, MS).

OBSERVATIONS

The description given below is mainly based on the skeleton of the male sperm whale (8.1 m in length) stranded at Krusadai Island except for some references made to the skull of the larger specimen (17.4 m).

Skull

Dorsal view: The skull (PI.I.A) is triangular in shape and shows asymmetry in size, shape and position of bones and openings. The maxillari'es are very massive, triangular in shape and adjoin the premaxiMairies throughout, their length reaching the top of the occipital crest. They are broad, flat and sharply pointed at the anterior end. The greater part of the skull is formed by the surfaces of maxilaries. Posteriorly, each maxillary shows a notch formed within its bone along the outer margin. Just opposite the notch and towards the interior of the bone, an elongated slit is present on each side which communicates to the ventral side (in the larger skull it is more like an aperture with an overhanging shelf loading to the ventral side). Behind the notch in the maxillary bone and bounding the maxillary bone an arm of the frontal bone extends forwards. On each side, a portion of 'the maxillary is inclined downwards. While the posterior end of the left maxillary joins by a suture with the inner surface of the occipital crest that of the right maxillary joins by a suture with the posterior end of right premaxillary (Fig. 1). The vomer which is narrow at either end and broad at midlength runs between the two premaxillaries. It is long and groved dorsally. The right nasal bone is situated at the posterior end of vomer. There is no trace of the

left nasal bone. The left bony nasal passage in the skull is large and well developed, the right one much less so. The nasal apertores open at the bottom of the cup-shaped recess of the skull.

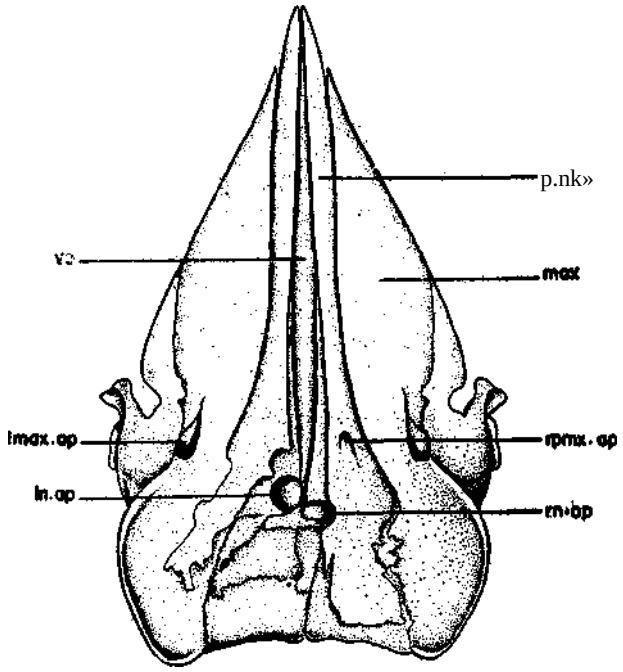

FIG. 1. Dorsal view of the sfculM of *P. macrocephalus*. Jimiaix. ap: left maxillary aperture; Inap: left nasal aperture; max: maxillary; p. max: premaxiUary; map: right nasal aperture; rpmx. ap: right premaxiUary aperture: vo: vomer.

The premaxiUaries project much beyond the anterior tip of vomer and also the anterior tips of maxillaries. The left premaxillary extends to a point beyond the posterior border of the nasal passage as a separate arm partly bounding the nasal passage, whereas the right premaxittary extends far beyond the posterior tip of left premaxillaiTy, almost reaching the top of the occipital crest. A foramen is present in the right premaxillary, closer to the nasal passage at a distance equal to 1/3 of its length from its posterior end, which is absent in the left premaxillary. Another point of asymmetry between the two premaxiUaries is that the left premaxillary is much wider at a point corresponding to the area immediately in front of the aperture in the right premaxillary. The posterior portions of both the premaxiUaries are flat and plate like. The premaxiliaries narrow down at albout half their length from the posterior end, then widen for some distance and again become narrow towards their anterior tips. Both the premaxiUaries are separate from one another throughout their length.

The base of the skull on the poster dorsal side assumes a shape of a trough, the wall of which is formed 'by the posterior ends of the maxillaries, the

pramaxillaries and the occipital crest (Fig.2). Posteriorly, the foramen magnum is bounded by two ventrally located, praminiant, bearirshaped and porous occipital condyles for articulation with the vertebral column (Fig.3).The foramen magnum is triangular in shape and is scarcely visible when viewed from behind. The occipital bones are fused into a single extensive bonie having an elevated crest which forms the wall at the positeior end of the skull. The occipital crest is spongy with grooves and ridges on the inner surface where the posterior ends of rnaxillaries and premaxillaries rest.

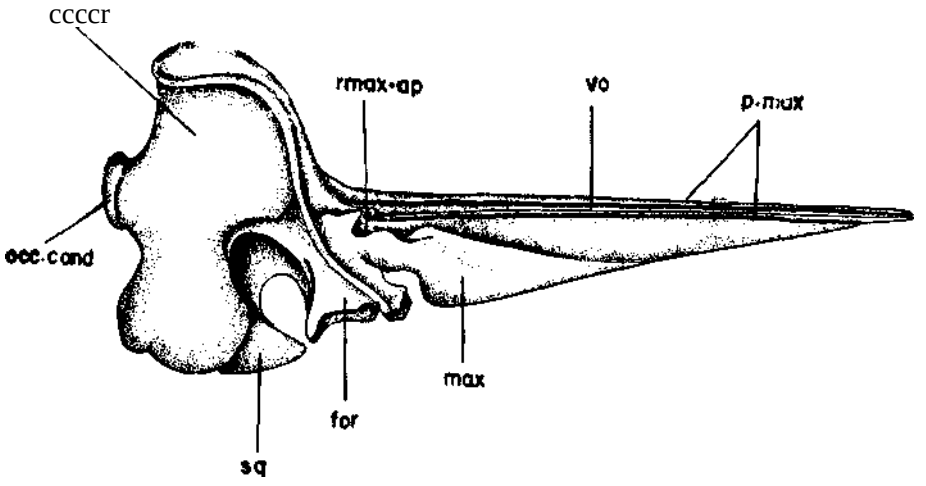

FIG. 2. Lateral view of the skull of *P. macroceplmius.* fir: frontal; max: maxillary; occ. cond: occiptal condyle; occ. cr: occipital crest; p. max: premaxillary; rmax. ap: right maxillary aperture; sq: squamosal; vo: vomer.

Ventral view: On the ventral side (PI. I B) each maxillary shows a conspicuous groove which terminates at a large foramen at the base. These grooves may be homologised with the dental grooves for the maxillary teeth. Behind the base of maxillary on each side, are the frontal and squamosal bones. The pterotic bones are massive, located at the base of the skull, overlapped by the occipital bone. At the base of vomer are the two palatines which are broad and fiat located dose to each other and roofed by the rnaxilllaries. The pterygoid bones are situated behind the palatines, the sutures between the palatines and pterygoids being highly wavy. The anterior ends of pterygoid bones form curved arms overlapping die palatines. In front of the tip of each palatine a small groove is formed on the inner,edge of maxillary. Along the outer side of pterygoid bones are alisphenoids close to which are located; the orbitosphenioids. The zygomatic process of the malar on each side extends as an arm over the frontal bone forming an oval orbit, its tip resting an the anterior projection of squamosal (Fig. 4). The bulla tympani on ©ach siue as situated at the posterior and of the skull immediately behind the squamosal as a small compact and round structure

nones.

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from where a tract of spongy bone leads to the exterior on either side to communicate with the external ear. The maximum size of bulla tympani is 7 cm. The skull of the larger specimen (17.4 m) shows similar skeletal characters. The conspicuous groove on the under surface of each maxillary bone is also present

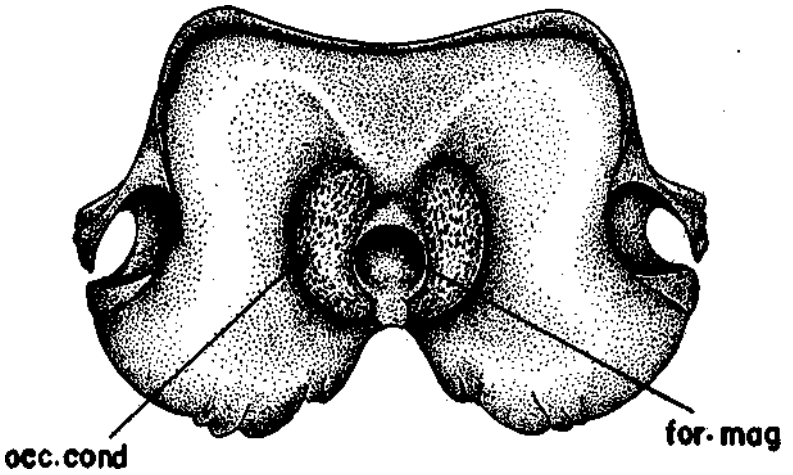
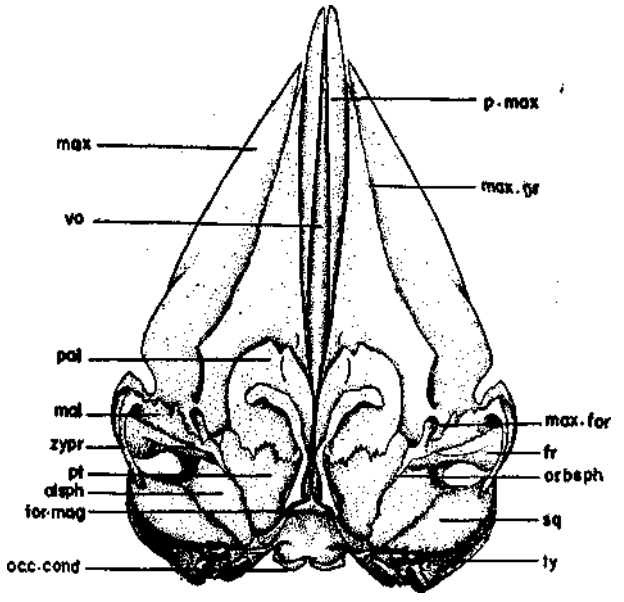
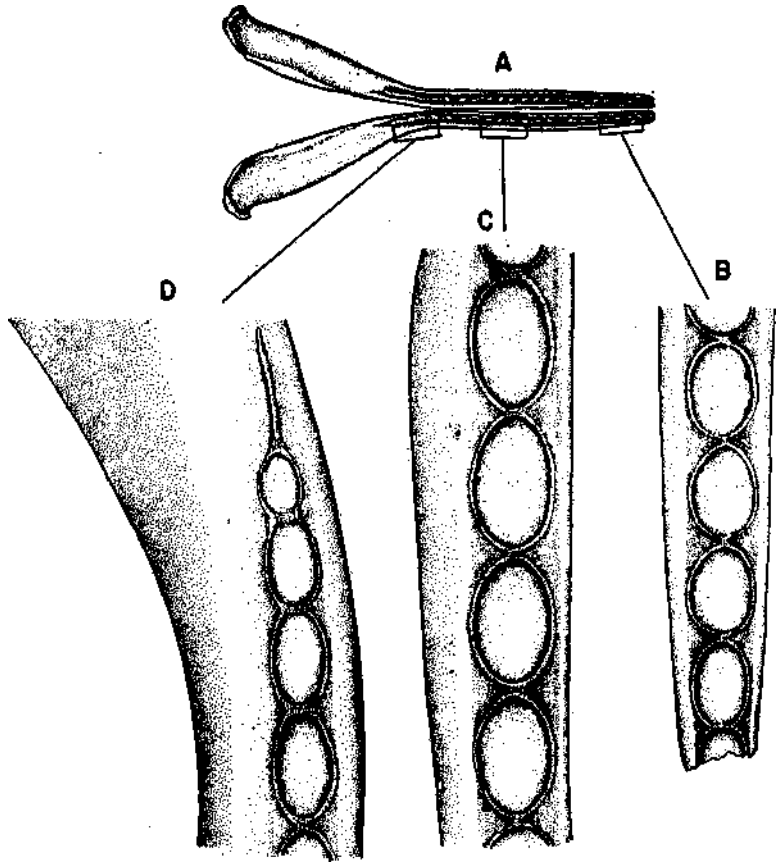


FIG. 3. Posterior view of the IskuM of *P. macrocephalus.* for. mag: foramen magnum; occ. cond: occipital condyle.



FlG. 4. Ventral view of the skull of *P. macrocephalus* aJspfa: aHsphemoid[1]; fr: frontal for. mag: foramen magnum; mal: malar; max. for: maxillary foramen; max. gr: maxillary groove; occ. cond: occipital condyle; orbsph: orbitosphenoid; pal: palatine; pt: pterygoid; sq: squamosal; ty' tympanic; zypr: zygomatic process;

Lower jaw: Each ramus of lower jaw is a 'bent bone, narrow anteriorly and broad and flat posteriorly (PI. I C). The symphysis of the right and left bone of the mandible is very highly developed. The upper portion of narrow part on each of the mandible provides the sockets for teeth a little distance beyond the bend (Fig. 5), the left one containing 22 sockets (length 3.0-5.0 cm; width 2.3-3.0 cm) and the right one 21 sockets (length 3.0-5.0 cm; width 2.1-3.0 cm). Symmetry in the position of sockets in each bone is seen only up to first 3 teeth from the anterior end. While the sockets are small, oval and distinct at the anterior end, they are 'large, elongate and also distinct 'in the middle region-. Posteriorly, they become narrow, smaller and less distinct (Fig. 5). The inner side of flattened portion of lower jaw on each sidfe encloses a large cavity up to about 1/3 the length from the posterior end. The posterior end of each ramus provides an articular facet for the upper jaw and skull. The lower surface of



HK3. 5. A) Lower jaw of *P. macroceplmlus.* B, C & D: entased views of tooth' sockets in the anterior, middle and posterior regions respectively on one side of the lower jaw.

the narrow portions of the mandible are sharp. On /the sides of the narrow portion about six apertures are seen. In 'the iowar-jaw bones of the larger skull, there are 23 sockets (length 6.0-14.0 cm; width 4.0-7.5 cm) on the left side and 22 sockets (length 6.0-14.0 cm; width 4.0-7.5 cm) on the right side. There aire about 10 apertures on the outer side of each half of the lower jaw in the symphysial region. The various measurements of the two skulls are given in, Table 1.

Teeth

Teeth are present only in the lower jaw (PI. I, D). In the upper jaw, the undersides of maxillaries have narrow grooves corresponding to the location of teeth in the upper jaw. There are 22 teeth on the left side and 21 on the right side. On the left side, to begin with, the first tooth is small and gently curved backwaters. The size of the teeth abruptly increases from first to second alter which it very gradually increases up to.teeth number 13/14. Thereafter, the size of the teeth gradually decreases to the last. When compared to the anterior teeth, the last four are narrow, long and somewhat straight having narrower bases than any of the anterior teeth. The last one is somewhat curved inwards. The first seventeen teeth are hollow up to more than half their height while from the 18th to the last (five numbers) there is reduction in the extension of cavity to less than half the height of the teeth. The teeth taper towards their tips which are rounded. Only the teeth from 3rd to 6th show small exposed dentine portions indicating that they are probably the most used. On the right side, the teeth are similar to those on the left side except that the 3rd, 4th and 5th showing the exposed dentine portions. The hollowness in the first seventeen teeth is up to more than half their height and from 18 to the last (4 numbers) it is less -than half of their height. The size of the teeth ranged from 4.3 to 7.3 cm.

Hyoid apparatus

This consists of five bones, namely the median basihyoid, two lateral sternohyoids and two anteriorly located stylohyoids (PI. 1 E). The basihyoid is narrow anteriorly and broad posteriorly. The vertical length is 20.5 cm and horizontal length is 26.0 cm. The sides are thickened. The two sternohyoids are flat bones with the outer margins thickened and with shallow depressions towards the dorsal side. The length of each bone is 28.5 cm and the width 15.0 cm. The articular portions are especially thickened. The stylohyoids are rod4ike, narrow anteriorly and broad posteriorly. The length of each bone is 33.5 cm and the thickness 8.0 cm. All the bones of hyoid apparatus are spongy.

Vertebral column

The vertebral column consists of 49 vertabrae. It could be divided into four sections, namely, cervical, thoracic, lumbar and caudal. The vertebrae are light and spongy characterised by a coarse rough surface. The vertebrae vary

TABLE 1. *Measurements of skulls of the sperm whale,* P. maorocepihalus

Total length of whale	8.1 m		17.4 m (estimated)	
Sex	Male		Male	
	(cm)	percent of condylo-basal length	(cm)	percent of condylo-bnsal length
1. Condylo-basal length	213.0	100.0	445.0	100.0
2. Length of rostrum (on a long axis from anterior tip of premaxillary bone to a point on a straight line opposite to maxillary notch)	135.0	63.4	232.0	52.1
3. Width of rostrum				
a) at its base	**84.0**	**39.4**	**153.0**	**34.4**
b) at middle length	**69.0**	**32.4**	**110.0**	**24.7**
4. Transverse width of bone at $ of its length from tip of rostrum				
a) Right maxillary	**29.0**	**13.6**	**44.0**	**9.9**
b) Left maxillary	**31.0**	**14.6**	**49.0**	**11.0**
c) Right premaxillary (in front of aperture)	**9.5**	**4.5**	**13.5**	**3.0**
d) Left premaxillary (in front of aperture)	**14.0**	**6.6**	**12.0**	**2.7**
5. Transverse width of bone at mid length				
a) Right maxillary	**31.0**	**14.6**	**44.0**	**9.9**
b) Left maxillary	**31.0**	**14.6**	**45.0**	**10.1**
c) Right premaxillary	**6.0**	**2.8**	**11.5**	**2.6**
d) Left premaxillary	**7.5**	**3.5**	**13.0**	**2.9**
6. Shortest distance between posterior edges of maxillary aperture.	**55.0**	**25.8**	**90.0**	**20.8**
7. Distance between anterior ends:				
a) of premaxillary (rostrum) and vomer	**24.0**	**11.3**	**50.0**	**11.2**
b) of premaxillary and maxillary	**17.0**	**8.0**	**56.0**	**12.6**
8. Height of occipital condyles	**23.5**	**11.0**	**39.0**	**8.8**
9. Width of foramen magnum	**14.7**	**6.9**	**19.5**	**4.4**
10, Distance from upper edge of foramen magnum to occiptal crest	**29.0**	**13.6**	**64.5**	**14.5**
11 Condylar width	**11.0**	**5.2**	**22.0**	**4.9**
12 Length of zygomatic bones	**30.0**	**14.1**	—	—
13. Diameter of orbits	**16.0**	**7.5**	**19.0**	**4.3**
14. Depth of orbits	**10.0**	**4.7**	**12.0**	**2.7**
15. Length:				
a) of lower jaw (long axis)	**169.0**	**79.3**	**368.0**	**82.6**
b) branch of lower jaw	**94.0**	**44.1**	**158.0**	**35.5**
c) of symphysis of lower jaw	**80.0**	**37.6**	**219.0**	**49.2**
16 Distance between anterior end of lower jaw and posterior end of alveolar row	**99.0**	**46.5,**	**255.0**	**57.3**
17. Width of mandibular condyles	**8.0**	**3.8**	**16.5**	**3.7**
18. Greatest height of lower jaw with coronoid process	**28.0**	**13.1**	**52.0**	**11.7**
19. Distance between mandibuar condyles	**77.5**	**36.4**	**102.0**	**22.9**

in shape and so also the intervertebral discs, to suit the shapes of corresponding contra of different vertebrae (PI. VI A, B). The sizes and weights of some vertebrae are given in Table 2.

TABLE 2. *Weights of vertebrae front different sections of vertebral column of the sperm whale* P. maorocephalus (Total length 8.1 m)

SI. No.	Vertebra	Weight (8)	SI. No.	Vertebra	Weight (g)
1.	Atlas	1700	9.	3rd caudal	900.0
2.	Fused cervical vertebrae	1400	10.	4th caudal	800.0
3.	1st thoracic	300	11.	10th caudal	300.0
4.	2nd .thoracic	250	12.	12th caudal	200.0
5.	10th thoracic	450	13.	18 th caudal	56.0
6.	4th lumbar	550	14.	21st caudal	12.0
7.	8th luolbar	750	15.	22nd caudal	7.5
8.	1st caudal	800	16.	23rd caudal	4.5

Cervical region; This consists of seven vertebrae. The first one is free while the following six vertebrae are fused. The first vertebra, namely, the atlas (PI. II A, B) is large, rectangular, compressed in the anteroHposterior direction. The neural canal is heart-shaped. The three angles of neural canal are rounded. The longer sides of the triangle are 'constricted at about half their length. On the anterior side of the atlas, two shallow articular surfaces with indistinct margins for accommodating the occipital condyles are present. The posterior surface of the atlas as well as the anterior surface of the fused cervical vertebrae also have articular surface with indistinct margins. The maximum height of the atlas is 31.0 cm and the width 46.5 cm. The height of the neural canal is 20.5 cm and the width 17.0 cm. The thickness of centrum is 5.5 cm. The neural arch of the atlas is convex, the central point of which rises above the body of the vertebra.

The second to seventh cervical vertebrae are fused, triangular in shape and compressed anteroposteriorliy. The neural canal is oval, broad at the base and narrow at the top, unlike the neural canal of the atlas (PI. II C, D). The six cervical vertebra© unite not only by their bodies but also by their spinous processes except at the bases of neural arches where they are separated from one another, forming passages for the oenebro-spinial cervical nerves. The top of the 'fused vertebrae shows a slit which is incomplete on the inner face, the slit starting from midway to extend[1] towards the posterior end. While the anterior surface is almost smooth, except for a small protuberance which fits into a recess on fee posterior facet of atlas, the posterior surface is cup-shaped with a deep depression. The fused, centra have a groove on fee ventral side along fee median

Mnie. The intervertebral disc is plate-like and 'bony, firmly attached over the posterior articular facet. The fused mass of six cervical vertebrae indicate elevations and depressions venitrolaterally, their number clearly indicating the fusion of six vertebra. The transverse processes ane indicated by two short jutting bony projections arising against the last cervical vertebra at the base of neural arch. The maximum height and width of the fused cervical vertebrae at the anterior face are 33 and 42.5 cm respectively. The thickness of centra together is 11 cm. The diameter of the neural camal is 15 cm.

Thoracic region: The centrum of the first thoracic vertebra is small and heart-shaped. Its anterior face is convex fitting into the concave depression provided by the posterior face of the fused cervical vertebrae (PI. II E). The posterior face of the centrum is flat (PI. II F). Corresponding to the shape of the centrum on the anterior and posterior faces, the :imitarverteibrial discs are also similarly shaped. The height and width of the anterior intervertebral disc of 1st thoracic vertebra are 8.5 and 16.3 cm respectively. The outer faces of the intervertebral discs are flat and smooth compared to itheir inner faces which are rough with ridges, grooves and holes. The neural arch is elevated, open at the top and encloses a large neural canal. The concavities in. ithe ventrolateral side of the centrum are less conspicuous than those on the following vertebrae. The centrum of the second thoracic vertebra is narrower, thicker and higher than the first. Similarly, the neural arch is also elevated with the result that the prezygapophyses are situated at a higher level. The neural canal is also smaller than that of the previous vetebra. The neural arch is dosed on top. The neural spine becomes moire and more distinct from the 3rd vertebra (PL IV B). The pastzygapophyses point postero-laterally up to 9th thioracic vertebra. The prezygapophyses in the first three •thoracic vertebrae are compressed but in the following thoracic vertebrae (up to 8th) they aire rounded. In this ninth vertebra they are reduced in size and somewhat elongate. The elongation further increases in the 10th vertebra (PI. II G, H) and in the lower most portion an additional smaller process appears (PI. II G). In the 1 lth thoracic vertebra only the forward^diirected, flat prezygapophyses are seen. The postzygapophyses become indistinct from the 10th vertebra. The shape of the intervertebral discs corresponds to that of centrum. The centra of thoracic vertebrae gradually increase in thickness and the neural spines become more distinct from the 3rd thoratic vertebra which also progressivdy increase in height. The neural canal is round im shape up to the 7th thoracic vertebra and from 8th vertebra it becomes oval in shape. Further, behind dt beoomes narrower and higher. The. 9th thoracic vertebra shows distinct transverse processes arising from the top of the centrum (nearer to the base of neural arch) and restricted to anterior half of the centrum. In the 10th thoracic vertebra, below the prezygapophyses of each side, a smaller process is devdoped pointing downwards. This smaller process is absent both in the 9th and the 11th thoracic vertebrae. The postoygapophyses lose their identity in the 11th vertebra. Both the faces of all the centra are rough with ridges and depressions

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of 1st to 5th thoracic vertebrae;
) - Lateral view of **7ih** to 1**2th**

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to fit into similar inner surfaces of the intervertebral discs. These discs are broad on top and narrow at the base (heairt^shaped). In the majority of the intervertebral discs, the outer surface shows a central smooth area followed by fibrous texture towards the periphery. The diameters of .the intervertebral discs range between 12 and 14.5 cm.

Lumbar region: In the lumbar vertebrae (PL III A, B and PI. IV C) the prezygapaphyses gradually become less conspicuous and lose their identity completely in the last lumbar vertebra, merging with the neural spine. The transverse processes from the first lumbar vertebra increase in width posteriorly up to the last lumbar vertebra and they curve backwards. The intervertebral discs are almost circular, their diameters ranging from 14 to 16.5 cm.

Caudal region: The first seven caudal vertebrae resemble generally .the lumbar vertebrae except in the shapes and the sizes of the neural arch, neural spine, prezygapophyses and the transverse processes (PI. Ill C, D). The conspicuous differences between the last lumbar vertebra (8th) and first caudal vertebra are the shape of the neural spine which is broader in the first caudal vertebra than in the last lumbar vertebra; the dorsal margin of neural spine is conspicuously angulaited unlike the almost ismooth curvature of the neural spine of the last lumbar vertebra; the anterior margin of the short transverse process of 1st caudal vertebra is curved backwards; and the prezyapophyses of the first caudal vertebra are less defined 'than those of the last lumbar vertebra. The caudal vertebrae from the 8th to the last differ from the anterior caudal vertebrae in the gradual reduction of neural spine, lack of transverse processes (PI. IV D) and in the shape of centrum (round up to 13th and rectangular up to 20th and globular in the last three) (PI. V A, B, C). The change from round to rectangular shape is more clear from centra of 16th to 20th caudal vertebrae which are also compressed. The transverse processes in die caudal vertebrae are seen up to 'the seventh vertebra:, the last not well demarcated from the centrum. The posterior edges of these process in the first four vertebrae curve forwards and in 5th to 7th they curve backwards. In the 8th caudal vertebra, in the place of a distinct transverse process, a slight ridge is present. No indication of transverse processes is found in the rest of the caudal vertebrae.

The neural spines attain maximum height at the 2nd and 3rd caudal vertebrae, decreasing in height thereafter up to a minimum at the 11th vertebra where the neural arch is still closed (PI. Ill E, F). In the 12th caudal vertebra, the neural arch is open (PI. Ill G, H). From the 13th caudal vertebra the neural canal is indicated as a depression along the median line of the dorsal side of the centrum (PI. V A). From the 16th caudal vertebra onwards the depression for the neural canal is confluent with .the two foramina on either side of it (PI. VA). The neural canal which is narrow and oval progressively becomes smaller from the 3rd caudal vertebra. The maximum size of the centrum is attained at the 2nd and 3rd caudal vertebrae and decreases in size thereafter (PI. IV D). From

the 9th caudal vertebra onwards there are two distinct foramina at the top as well as on the base of the centrum on either side of the median line. The foramina on the dorsal side aire interconnected with those on the ventral side and they shift closer to median line from 'the 12th caudal vertebra (PI. IV D). The ventral foramina on the 13tlh, 14th and 15th caudal vertebrae are located in circular depressions whereas in the following caudal vertebrae, from 16th to 20th, they are located in an open narrow canal or groove. (PI. V B). The dorsal and ventral grooves in 21st to 23rd caudal vertebrae open one into the other with the result that the distinctness of dorsal and ventral tormina is lost.

From lStiri caudal vertebra onwards, the external surfaces of the intervertebral discs _are uniformly smooth. The posterior and anterior faces of centra of the 14th to 20th caudal vertebrae show projections in the central portion which fit into small depressions ait the centre of .the inner face of the intervertebral discs. The ridges and depressions on the inner sides of the intervertebral discs and the covered surfaces of the centra gradually become less pronounced from 15th to 20th vertebrae. Distinct intervertebral discs are present up to the 21st caudal vertebra, the diameter of the discs ranging from 17.5 to 2.6 cm (anterior to posterior end). The posterior intervertebral disc of 21st vertebra is fused with the centrum.

From the atlas the height of the vertebral column increases to the fused cervical vertebrae behind which it declines to .the first thoracic. Thereafter it gradually rises up to 2/3 caudal vertebrae and gently slopes towards the tip of vertebral column. Thus, there is only one .main sloping bend in the vertebral column .passing into the thoracic section. The measurements of different vertebrae are given in Tables 2 & 3.

TABLE 3. *Measurements of different vertebrae of the sperm whale* P. macroeephalus (total length 8.1 m).

SI. No.	Vertebra	Height (including neural arch) (cm)	Width (including transverse processes) (cm)	Thickness of centrum (cm)	Diameter c neural cans (maximum (cm)
1.	Atlas	31.0	46.5	5.5	20.5
2.	Fused cervical (2-7)	33.0	42.5	11.0	15.0
3.	1st thoracic	29.5	31.0	6.0	16.0
4.	10 th thoracic	33.0	30.0	10.0	11.0
5.	4th lumbar	37.0	31.0	12.5	10.0
6.	2nd caudal	37.5	34.5	15.0	8.0
7.	12th caudal	16.5	14.0	7.5	—
8.	18th caudal	6.8	8.0	4.0	—
9.	23rd caudal		—,	2.7	

il vciiebrae; 1') - Chevron

(Facing Page 229}

There are 10 chevron bones (PI. V D), the first one articulating between 3rd and 4th caudal > vertebrae and the following between a padr of successive vertebrae (4th & 5th, 5th & 6th and[1] so on). There is no trace of any rudimentary chevron bones between 1st and 2nd and 2nd and 3rd caudal vertebrae. The first chevron bone is typically 'Y' shaped and columnar. The (height of the bone is 23.0 cm and the width 5.0 cm. The second is the largest in the series (height 27.0 and width 9.2 cm) the base of 'Y' gradually broadening posteriorly. With the shortening in the length of the bones posteriorly, the 'Y' shaped nature is lost, the last one having only the upper arms of 'Y' (height 4.7 and width 4.5 cm). The articular surfaces of the first two chevron bones are head-like whereas these of the following are elongated in the antero-posterior direction. All the chevron bones are spongy.

Ribs

There are 10 pairs of ribs (PI. IV A) articulating with the first 10 thoracic vertebrae. The first pair is the shortest of all. The size gradually increases posteriorly, reaching the maximum in the fifth rib, behind which the size again decreases gradually. The first pair of ribs measure 73.0 to 76.5 cm in length (along the curvature of the bone). The 4/5th pairs measure 128.0.to 131 cm in length. The lengths of fte last pair of ribs are 78.8 and 81.5 cm. The first rib is very much flattened throughout its length as also the second. From the third onwards, flattening decreases especially ait the angle. All the following ribs are similar in shape. Except for the first and the last, the ribs have two articular facets, the capiitulum and the toberculum, at the dorsal end. All the ribs are ossified and only slightly spongy. For all the ribs, the middle portion (angle) is narrowest and the shaft broadest. The ribs have blunt ends with rough surfaces.

Sternum

Since the sternal bones of the present specimen could not be recovered, a brief description of the .same according to Berzin (1972) is given below in order to make the account complete.

The sterum is large and massive but markedly shortened. It is triangular in shape with one to six segments, separate or united to varying degrees. The total length of the sterum equals or very slightly exceeds the width. The upper lateral corners form protuberances with rough oval surfaces for articulation surfaces for union with cartilage of sternal ribs, the number of which is variable from 3 to 5 pairs.

Limbs

The scapula (PI. VI C) is high, its height exceeding the width (maximum height 44 cm, width 39 em). The acromion is a flat process, narrow at the proximal and broad at the distal end (14.7 cm in length). Its tap is pointed.

The coraooid process is located immediately below the acromion and directly above the articular notch. It is wide ait the base and narrow ait the tip. The socket is large with an oval concavity (maximum diameter 12.5 cm).

Humerus (23 cm in length) is a separate bone (PI. VI C) articulating above with the scapula through a hemispherical highly spongy bone fitting into the socket of the scapula and resting on the head of humerus. The upper portion of humerus is rounded, whereas the lower portion is flat providing for two distinct articular facets for the .articulation of radius and ulna through the intermediary of tightly fitting spongy bony plates. The humerus is marrow at the middle and broad at the ends. A small bony tubercle is present on the anterior side where the bone begins to narrow.

The radius (8 cm in length) and ulna (17 cm in length) articulate at the base of the humerus (PL VI C) through two separate spongy bony plates which are flat towards the humerus and convex towards the (radius and ulna. The dorsal ends of both the radius and the ulna provide concavities for articulation. The ulna is shorter than the radius. Both are broad ait either end and narrow at the middle. The ulna has a posteriorly directed, somewhat curved short process at its proximal end. The tower ends of both the radius 'and ulna are flat with tubercles, holes and ridges.

The carpal bones are dome-shaped and are of various sizes. The curved surface is traversed by ridge, grooves and holes, making the surface rough.

Phalanges are flat and broad at either ends, one and being thicker than the other. Since the complete set of earpals and phalanges could not be recovered it has not been possible to indicate the correct number of carpal bones and their arrangement in each of the limbs and the number of phalanges in each of the digits.

The number of phalanges in each digit varies rom 1 to 2 in first; 5-6 in the second; 4-6 in third; 4-5 in fourth; and 2-3 in fifth (Berzin, 1972).

, *Pelvic bones*

The pelvic bones of the present specimen could not be recovered. Therefore, the description of pelvic bones after Berzin (1972) is given below.

The sperm whale has no true pelvic girdle. Only small pelvic bones are present which are not connected with the vertebral column. In most cases, these are solitary and elongate bones situated horizontally, almost parallel to vertebral column opposite the first caudal vertebra.

REMARKS

The skeleton of sperm whale, especially of the cranial part, shows great variations from the usual structure of many cetaceans. Among the individuals of

the same species differences occur in the position and arrangement of different parts of the skeleton to some extent. Berzin (1972) dealt with the details of different portions of skeleton fairly extensively, also quoting the description of a few others who had examined skeletons of the sperm whale. While examining the skuHs of the sperm whales stranded at Krusadai and Manauli Islands, it has been observed that the asymmetry in size, shape and position of bones and openings of the skull is well pronounced leading to complete reduction' of several of the paired bones and the widenings, elongation, flattening* and fwistings of the many cranial and facial bones make it 'difficult to homologise to those of other cetacea as pointed out by Berzin (1972).

Conspicuous grooves on' the under surface of 'the maxillaries were found in both the skulls of adolescent male (8.1 m) and adult male (17.4 m). According to Berzin (1972), Flower (1867) regarded these grooves as remnants of the dental grooves of the maxillary teeth, but Bascbma (1938) rejected it. However, 'it is evident from the present observations that the grooves remain almost throughout the life of the sperm whale. Maxillary teeth have not been found, in both the specimens examined in the present study. The skulls of both the specimens show similarities in arrangement of corresponding bones..

The ratio of symphysis to the remaining portion of lower jaw bone in the smaller specimen (1:1.18) is less than that in large specimen (1:0.72). The number of teeth in each side of lower jaw varies considerably.

In the present study, in 'the smaller specimen there were 22 teeth on the left side and 21 on the right side. In the bigger specimen, there were 23 sockets on the left side and 22 on the right side (as judged from number of sockets). In the smaller specimen, first 8 teeth on the left side and first six on r^gbt side were exposed (James and Soundarairiajain 1980). According to Niishiwaki et ai (1958) quoted by Berzin (1972), the teeth erupt when the length of male and female sperm whales is about 9-10 m at the age of 4.5 years coinciding with sexual maturity. According to Berzin (1972), the male attains sexual maturity at 9-10 m in length. It is of significance that the teeth had already erupted in the present smaller specimen (8.1 m) Which must have been only an adolescent.

The characters of hyoid bones of the present whale agree with the description of these bones by Berzin (1972).

In the vertebral column, the cervical section contained a free aitlas and six fused vertebrae. That the fused mass consists of six vertebrae could be made out from the number of distinct ridges and grooves on the ventrolateral portions of the fused vertebrae. It has been stated by Berzin (1972) that the form of the vertebral foramen in the atlas of the sperm whale described by Flower resembles an isosceles triangle, one angle of which is directed downward, the upper side nearly straight and the angles rounded. Judging from the photograph (Omura et al (1962), the vertebral foramen of the atlas has suck a shape in a sperm whale from'the waters of Japan. According to Berzin (1972), the vertebral

foramen of the atlas of a sperm whale from the collections of ZM AN SSSR (Zoological Museum of the Academy of Science of the USSR) is not as wide and more 'T' shaped, with almost equal width and height (25 cm). According to Berzin, 1972), Gray distinguished a separate species of sperm whale from a single specimen caught off the Shores of Australia on the basis of the form of the vertebral canal of the atlas and of 'the entire cervical section. While the details of Gray's species are not available, it is obvious that "the vertebral foramen in the atlas of the present specimen (8.1 m) differs strikingly from an isosceles triangle and the 'T' shaped vertebral foramen mentioned in the above two oases, in that it is heart shaped, PI. II A, B) and longer than wide (length 20.5 and width 17 cm).

The thoracic section has eleven vertebrae but only ten ribs were found. No ring is formed by .the lower transverse process aind upper process in 9th thoracic vertebra as quoted by Berzin (1972). According to Berzin (1972), there are 11 ribs, the last one much smaller than the preceding ribs and nearly straight. In the present specimen the last pair of tibs is not conspicuously smaller than the previous one.

The lumbar section of vertebral column has eight vertebrae. The caudal sectiom has 23 vertebrae. According to Berzin (1972), the boundary between the lumbar and caudal sections is determined by the appearance of chevron bones and the presence of articulation areas on the lower surface of the vertebrae with which they are articulated and the first 11 to 14 vertebrae of the section have such bones at their bases. But in the present study, only 10 chevron bones were found, the first one articulating between 3rd and 4th caudal vertebrae and the remaining articulating in between the succeeding pairs of vertebrae. No articular facets for chevron bones could be observed in the first two caudal vertebrae. However, from the differences noticed among the last lumlbar vertebra and first caudal vertebra the boundary between the two sections could be determined.

In the present material the three bones of the forefenb, namely humerus, radius and ulna, were separate from each other and not united as menitoned by Berzin (1972).

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